US007457071B1

(12) **United States Patent**
Sheh

(10) **Patent No.: US 7,457,071 B1**
(45) **Date of Patent: Nov. 25, 2008**

(54) **LOCATING AN INITIAL SERVO TRACK IN ORDER TO SERVO WRITE A DISK DRIVE FROM SPIRAL TRACKS**

(75) Inventor: **Edgar D. Sheh**, San Jose, CA (US)

(73) Assignee: **Western Digital Technologies, Inc.**, Lake Forest, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 121 days.

(21) Appl. No.: **11/500,568**

(22) Filed: **Aug. 8, 2006**

(51) **Int. Cl.**
G11B 21/02 (2006.01)
G11B 5/09 (2006.01)
G11B 5/596 (2006.01)

(52) **U.S. Cl.** **360/75**; 360/48; 360/77.08

(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,576,906	A	11/1996	Fisher et al.	
5,668,679	A	9/1997	Swearingen et al.	
5,754,353	A	5/1998	Behrens et al.	
5,761,212	A	6/1998	Foland, Jr. et al.	
5,831,888	A	11/1998	Glover	
6,021,012	A	2/2000	Bang	
6,023,386	A	2/2000	Reed et al.	
6,091,564	A	7/2000	Codilian et al.	
6,249,896	B1	6/2001	Ho et al.	
6,292,318	B1	9/2001	Hayashi	
6,304,407	B1	10/2001	Baker et al.	
6,411,453	B1	6/2002	Chainer et al.	
6,429,989	B1	8/2002	Schultz et al.	
6,507,450	B1	1/2003	Elliott	
6,519,107	B1	2/2003	Ehrlich et al.	
6,587,293	B1	7/2003	Ding et al.	
6,603,622	B1	8/2003	Christiansen et al.	
6,704,156	B1	3/2004	Baker et al.	
6,738,205	B1	5/2004	Moran et al.	
6,985,316	B1	1/2006	Liikanen et al.	
7,054,083	B2	5/2006	Ehrlich	
7,088,533	B1	8/2006	Shepherd et al.	
7,330,327	B1 *	2/2008	Chue et al.	360/75
2007/0285822	A1 *	12/2007	Lau	360/69

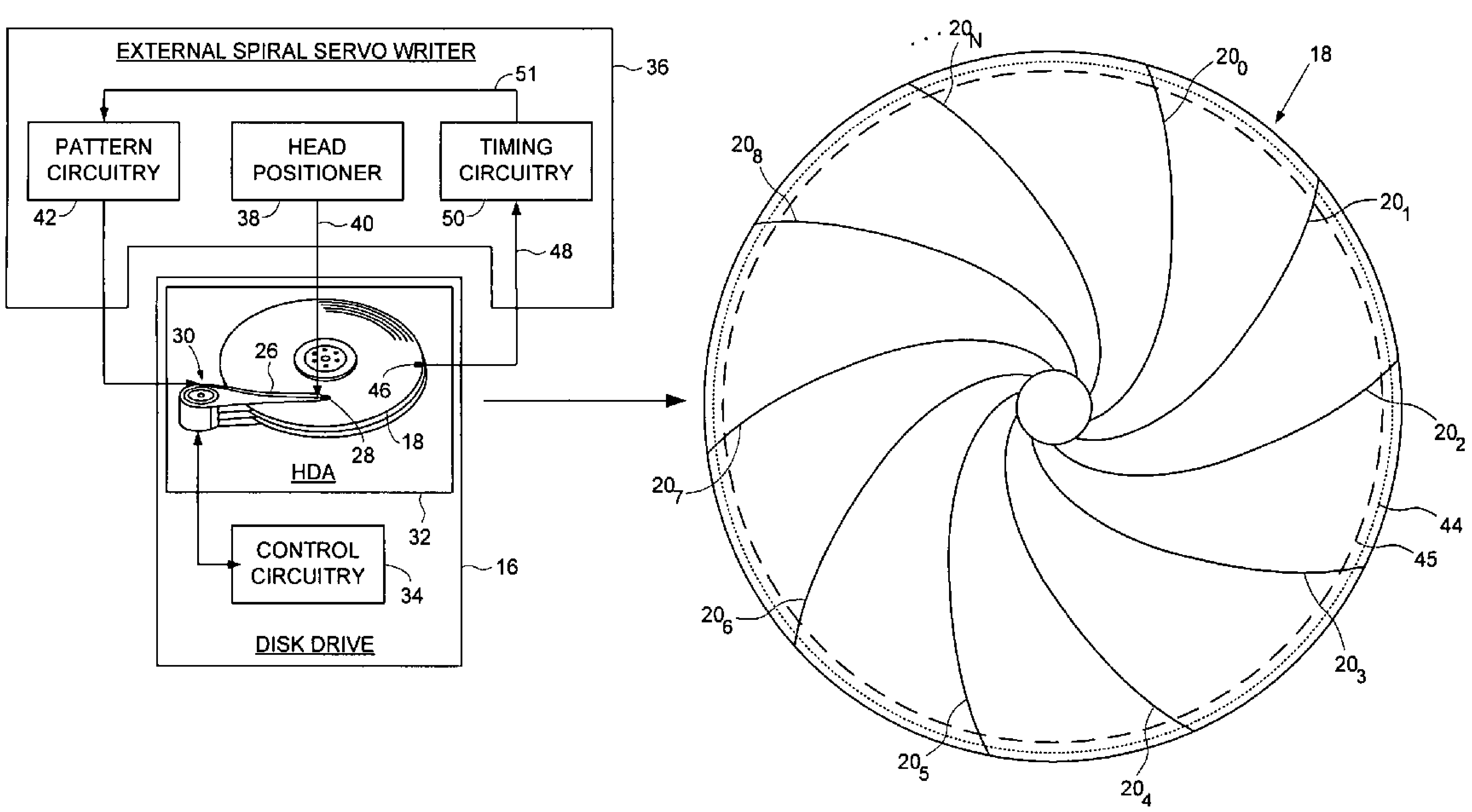
* cited by examiner

Primary Examiner—Joseph Feild
Assistant Examiner—Jason Olson
(74) *Attorney, Agent, or Firm*—Howard H. Sheerin, Esq.

(57) **ABSTRACT**

An embodiment of the present invention comprises a method of writing product servo sectors to a disk of a disk drive. The disk comprises a plurality of spiral tracks each having a high frequency signal interrupted at a predetermined interval by a sync mark. The head internal to the disk drive is used to read the spiral tracks to generate a read signal which is processed to detect the sync marks. An aberration is detected in the detected sync marks in order to locate an initial radial location of the head with respect to the disk. The read signal representing the high frequency signal in the spiral tracks is processed to generate a position error signal (PES) used to maintain the head along a substantially circular target path while using the head internal to the disk drive to write the product servo sectors along the circular target path.

10 Claims, 10 Drawing Sheets



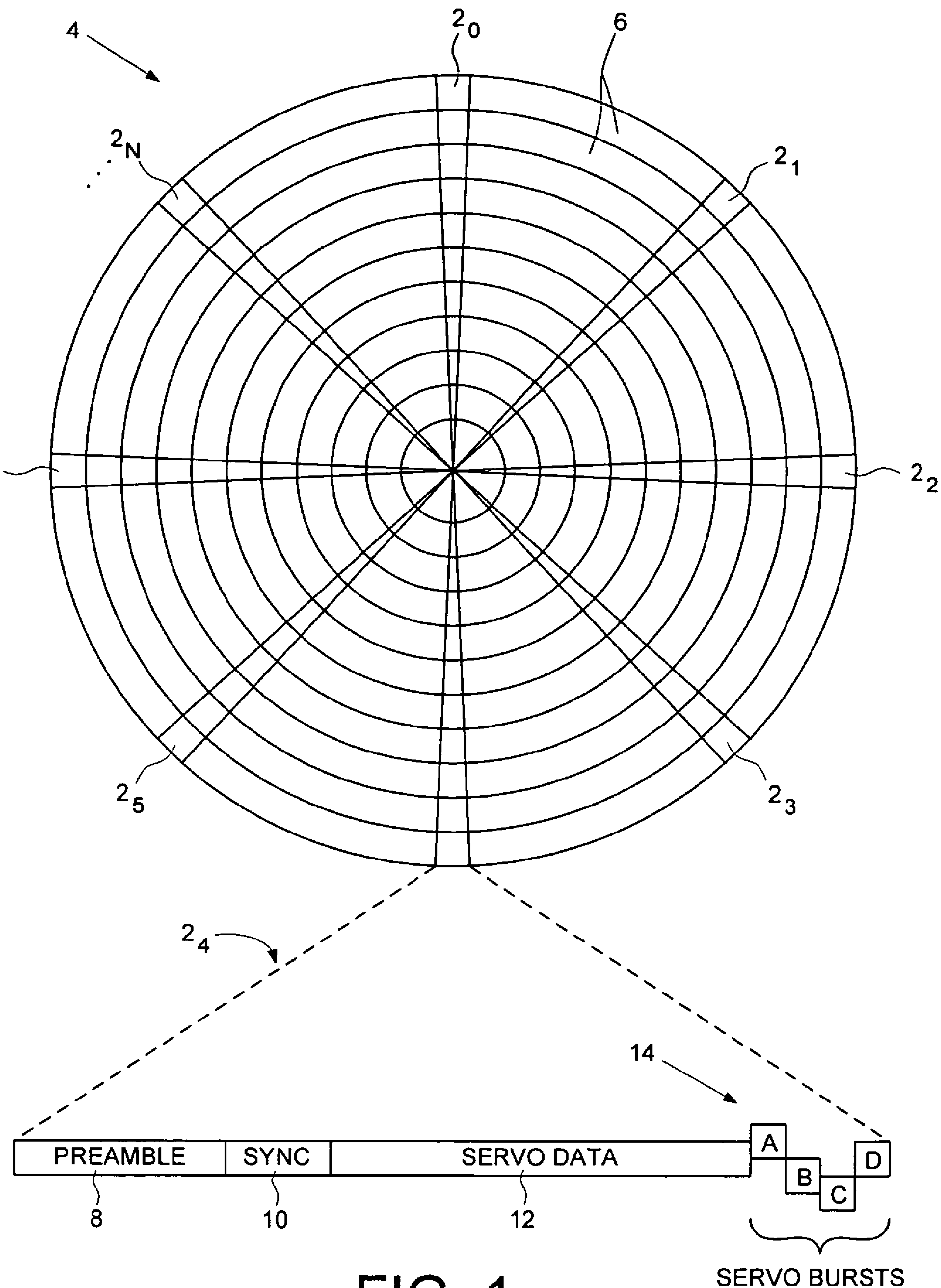


FIG. 1
(Prior Art)

FIG. 2B

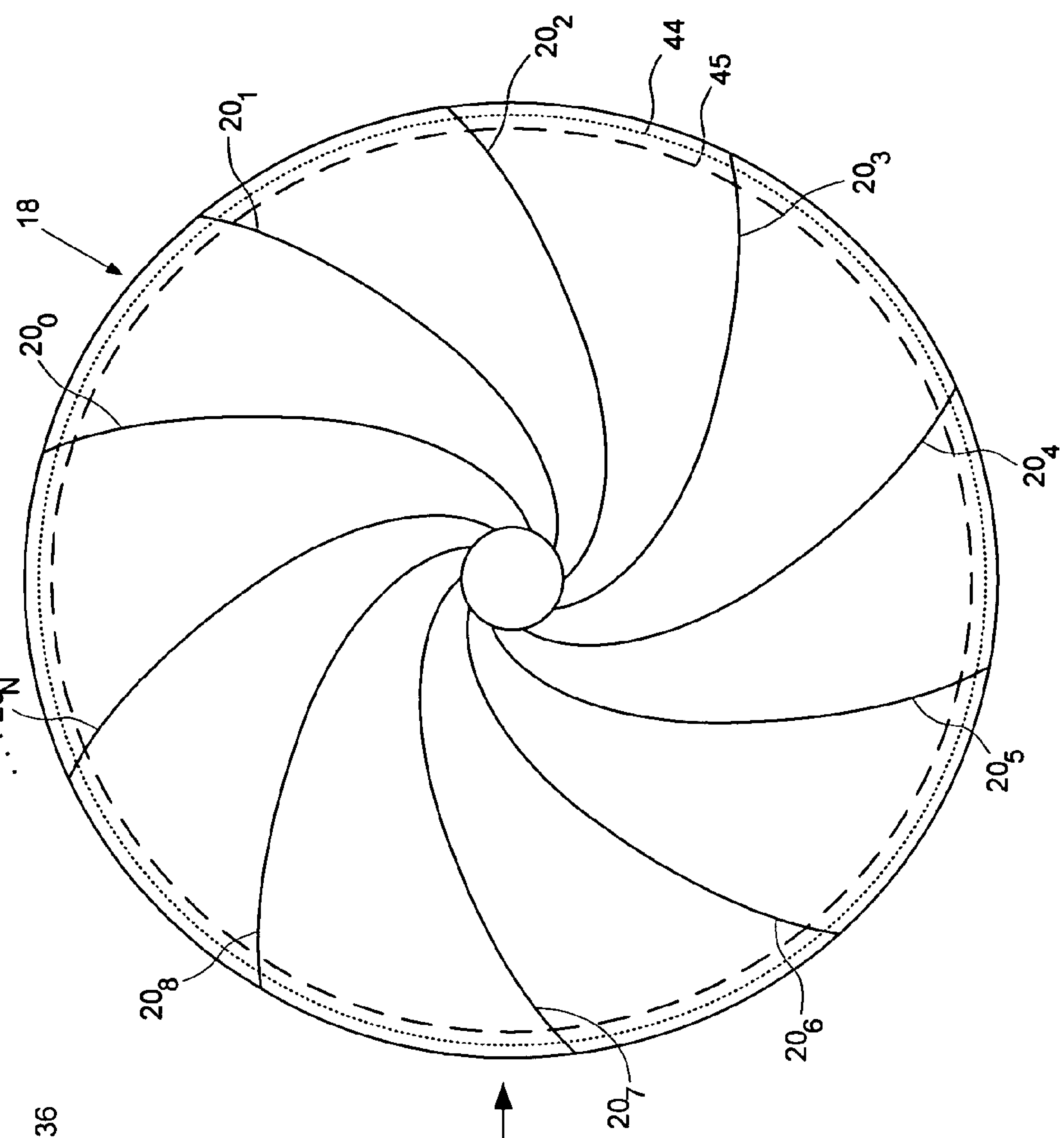
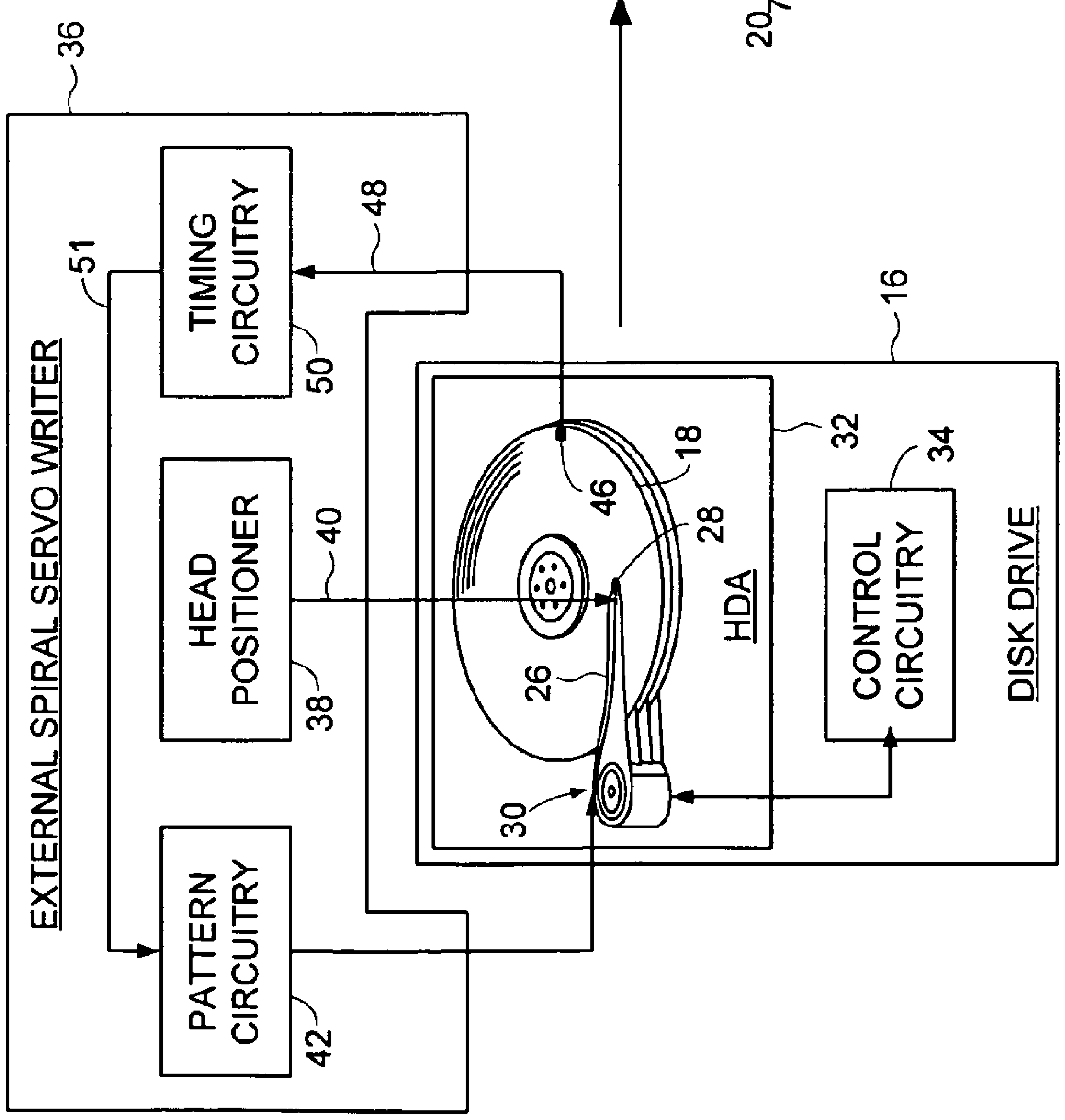

18
44
45
20_0
20_1
20_2
20_3
20_4
20_5
20_6
20_7
20_8
20_N

FIG. 2A


EXTERNAL SPIRAL SERVO WRITER
36
TIMING CIRCUITRY
50
51
48
HEAD POSITIONER
38
40
PATTERN CIRCUITRY
42
HDA
DISK DRIVE
16
32
34
CONTROL CIRCUITRY
18
46
28
26
30

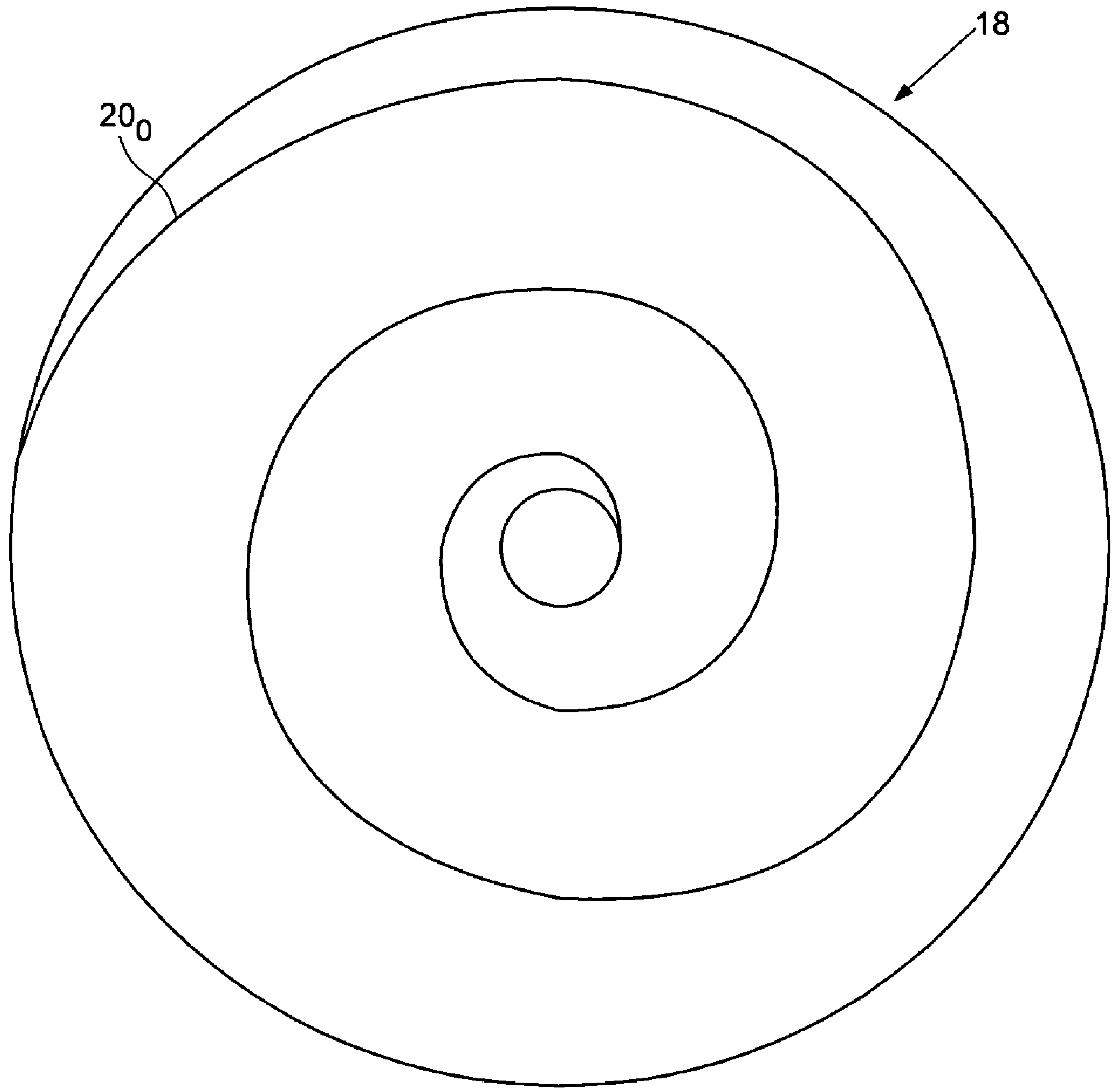
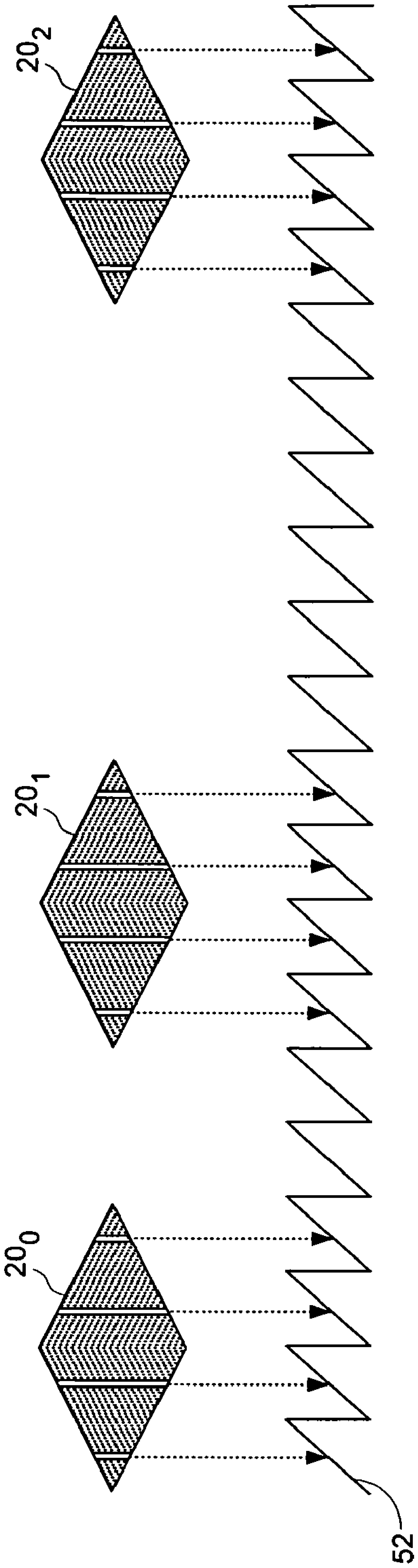


FIG. 3

FIG. 4A



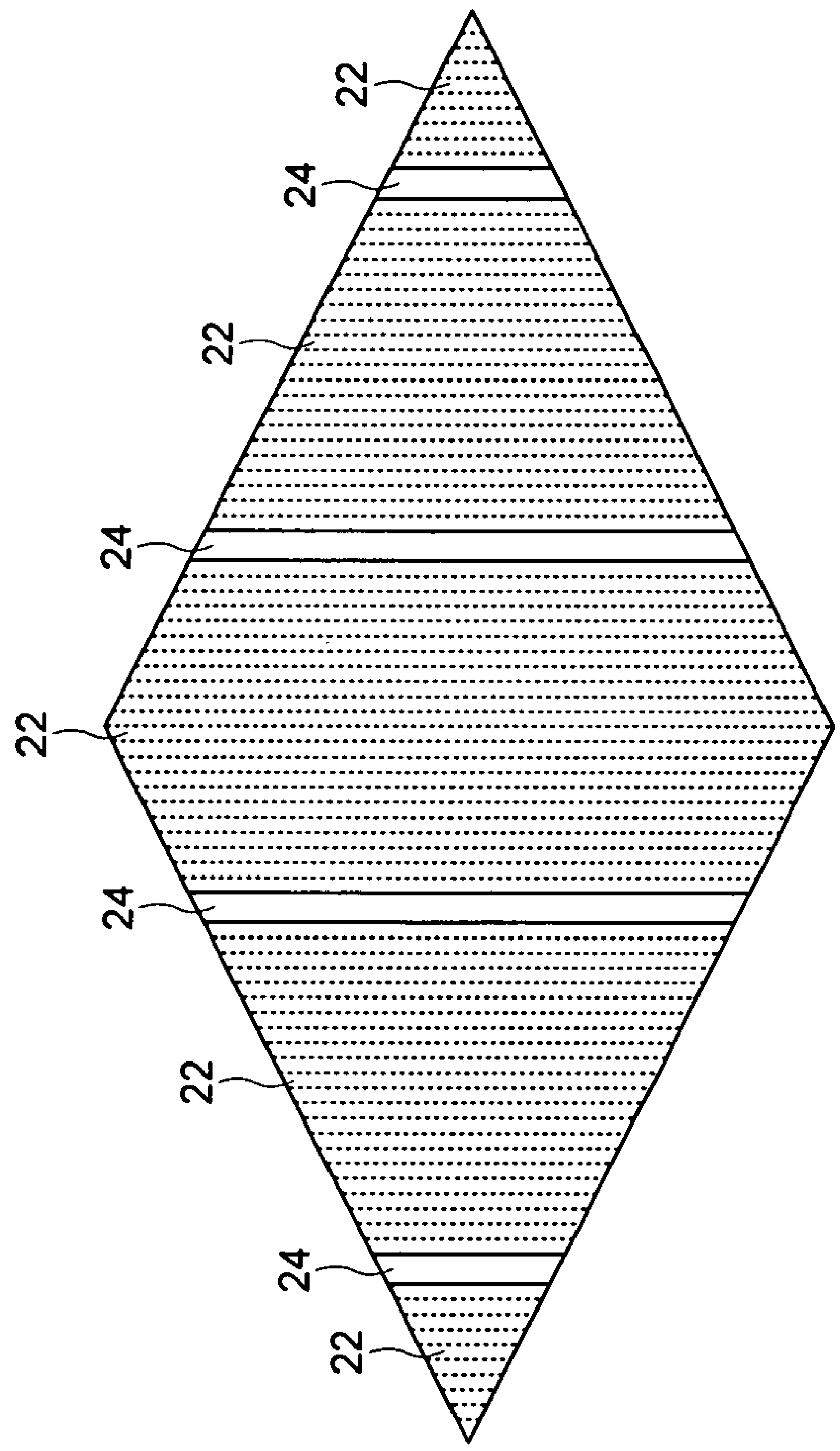


FIG. 4B

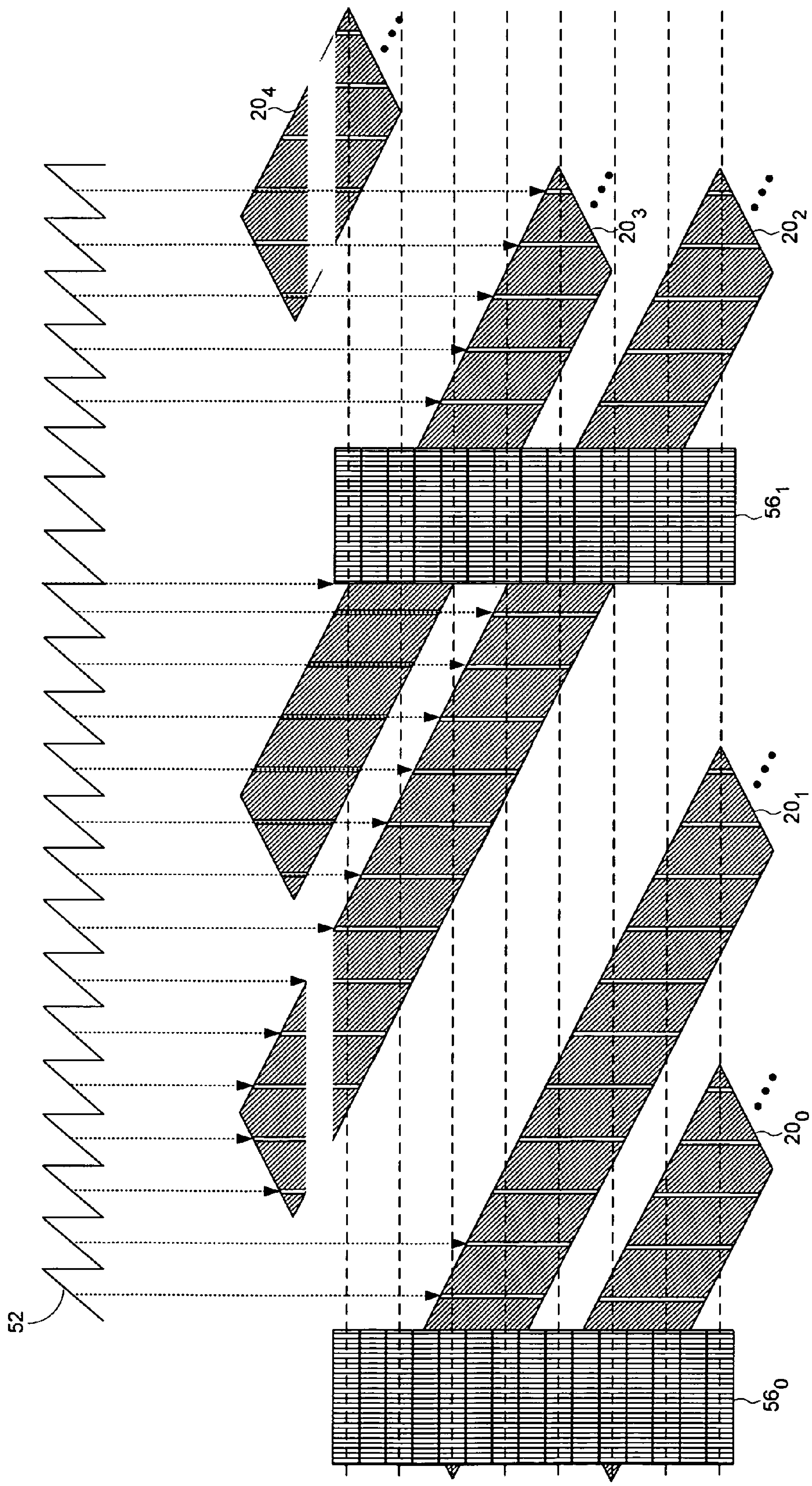


FIG. 5

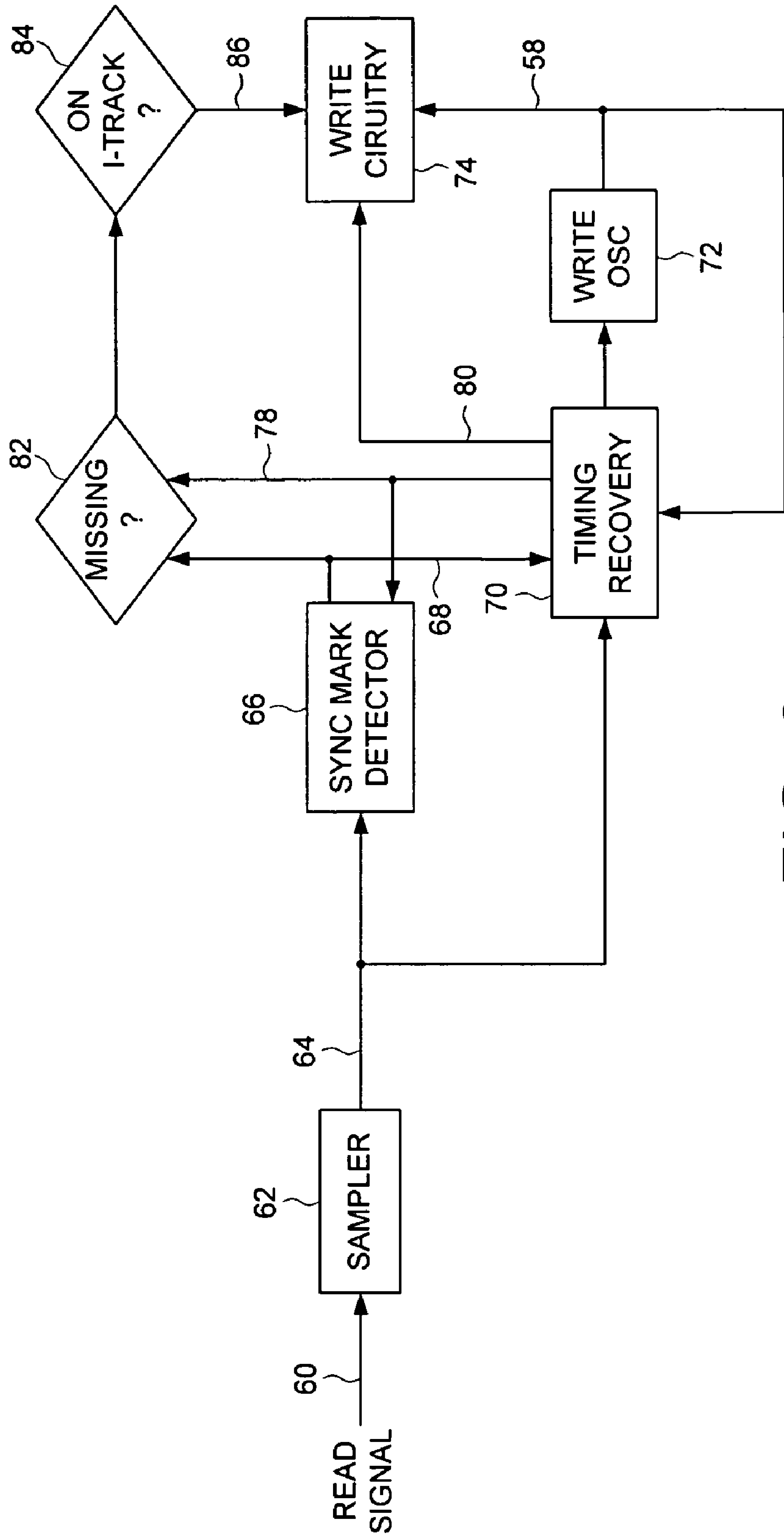
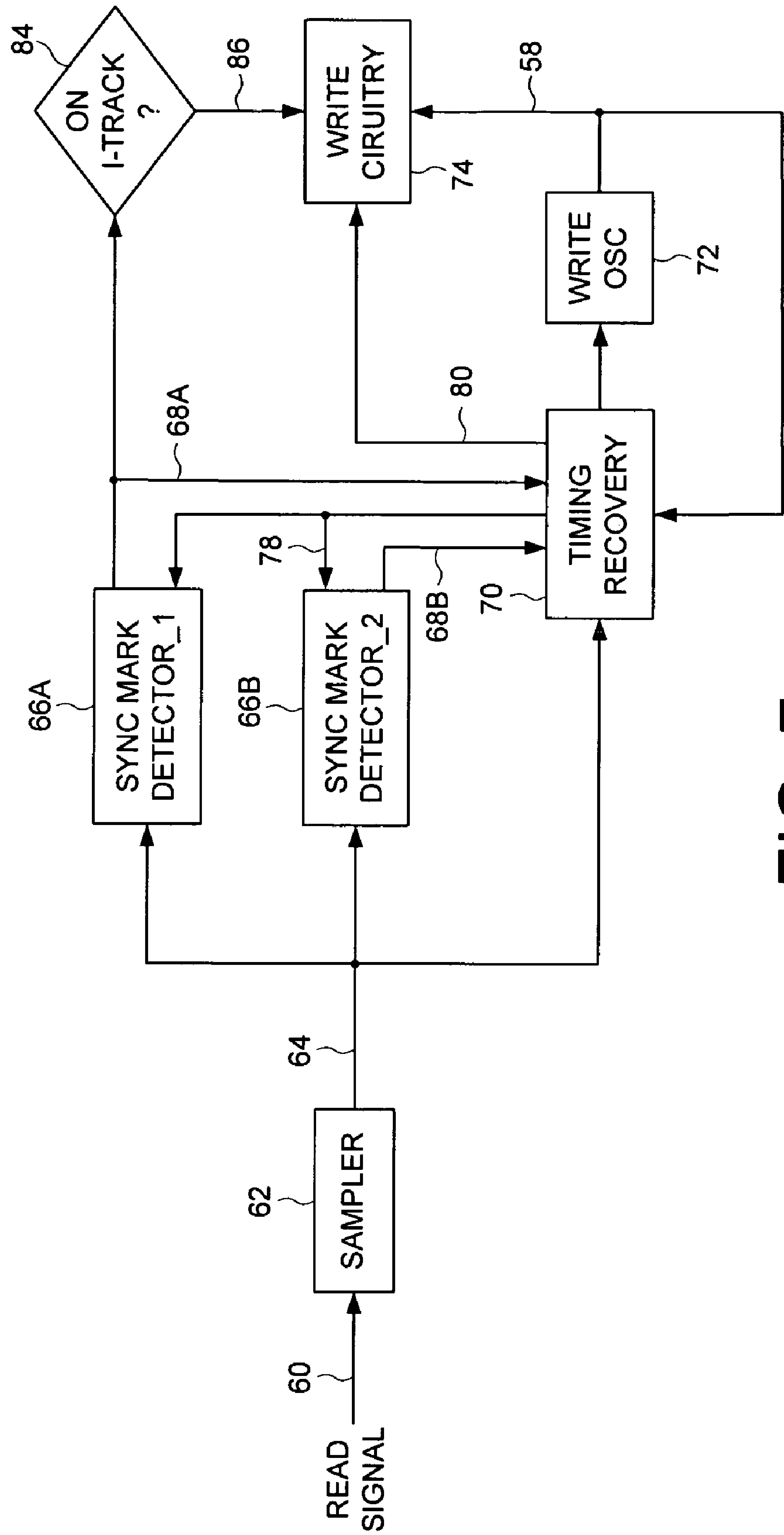

READ SIGNAL
60
SAMPLER
62
64
SYNC MARK DETECTOR
66
68
TIMING RECOVERY
70
MISSING ?
82
78
80
WRITE OSC
72
ON I-TRACK ?
84
86
WRITE CIRUITRY
74
58

FIG. 6



READ SIGNAL
60
SAMPLER
62
64
SYNC MARK DETECTOR_1
66A
SYNC MARK DETECTOR_2
66B
68A
68B
78
TIMING RECOVERY
70
80
WRITE OSC
72
WRITE CIRUITRY
74
58
ON I-TRACK ?
84
86

FIG. 7

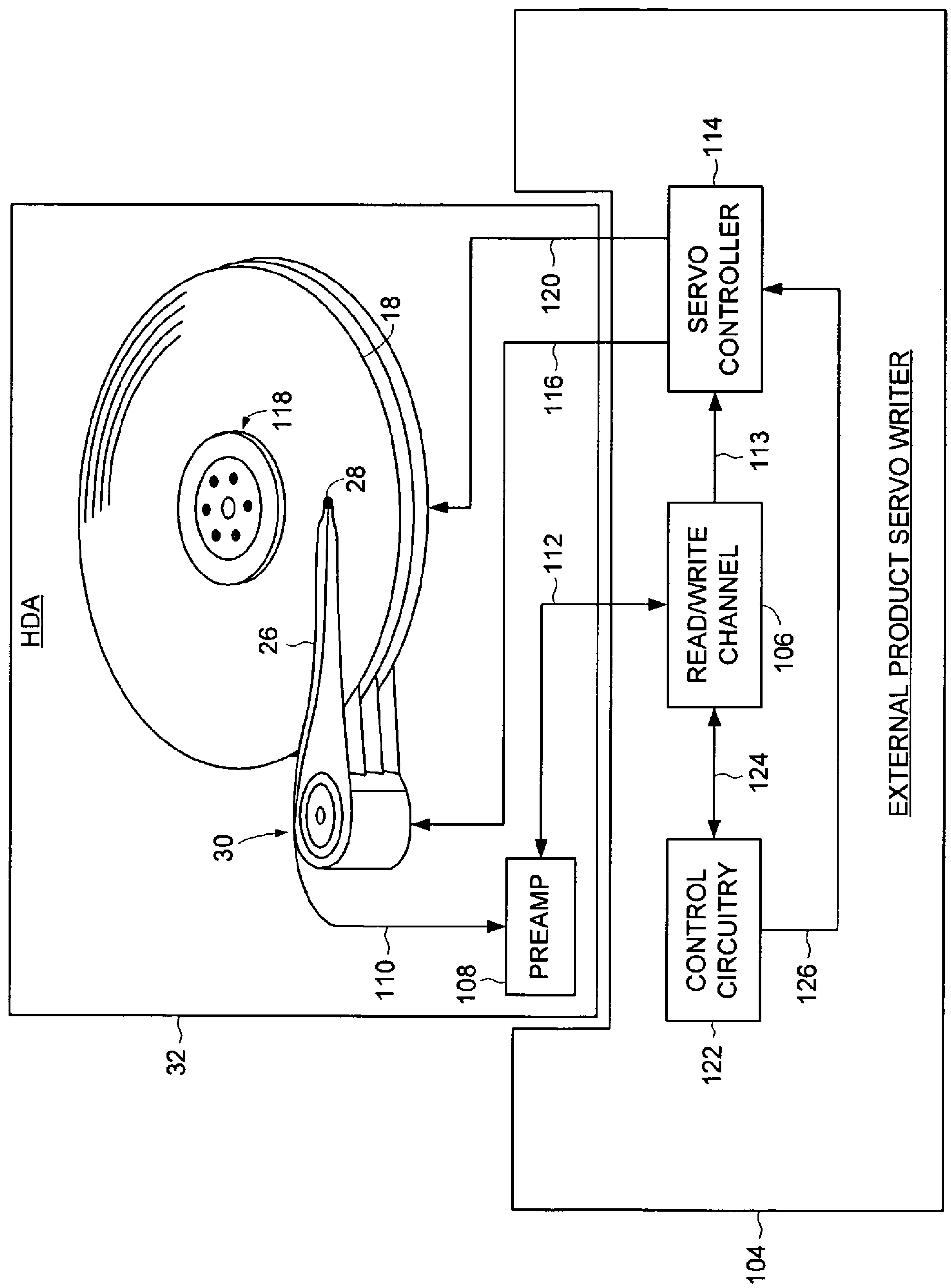
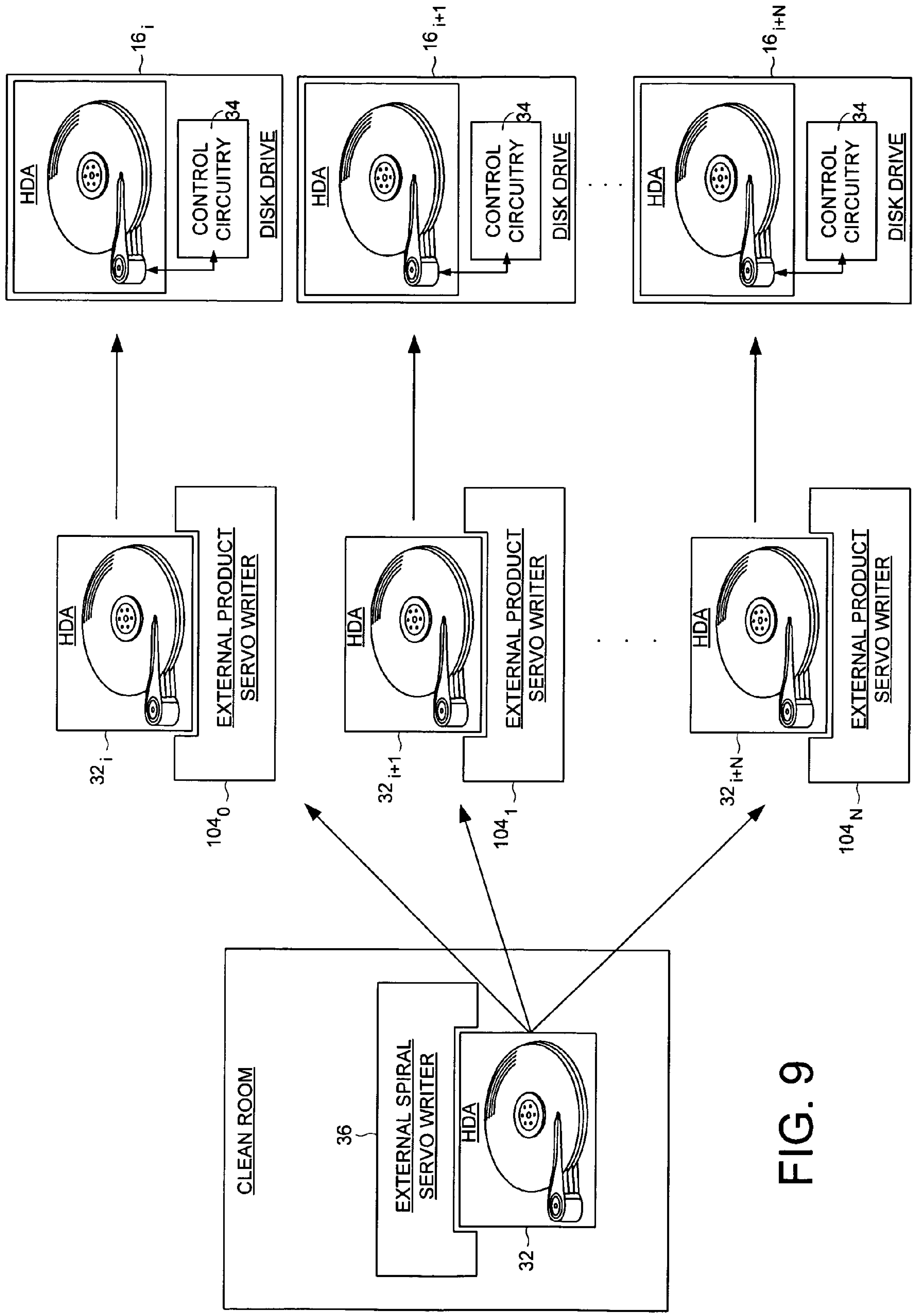
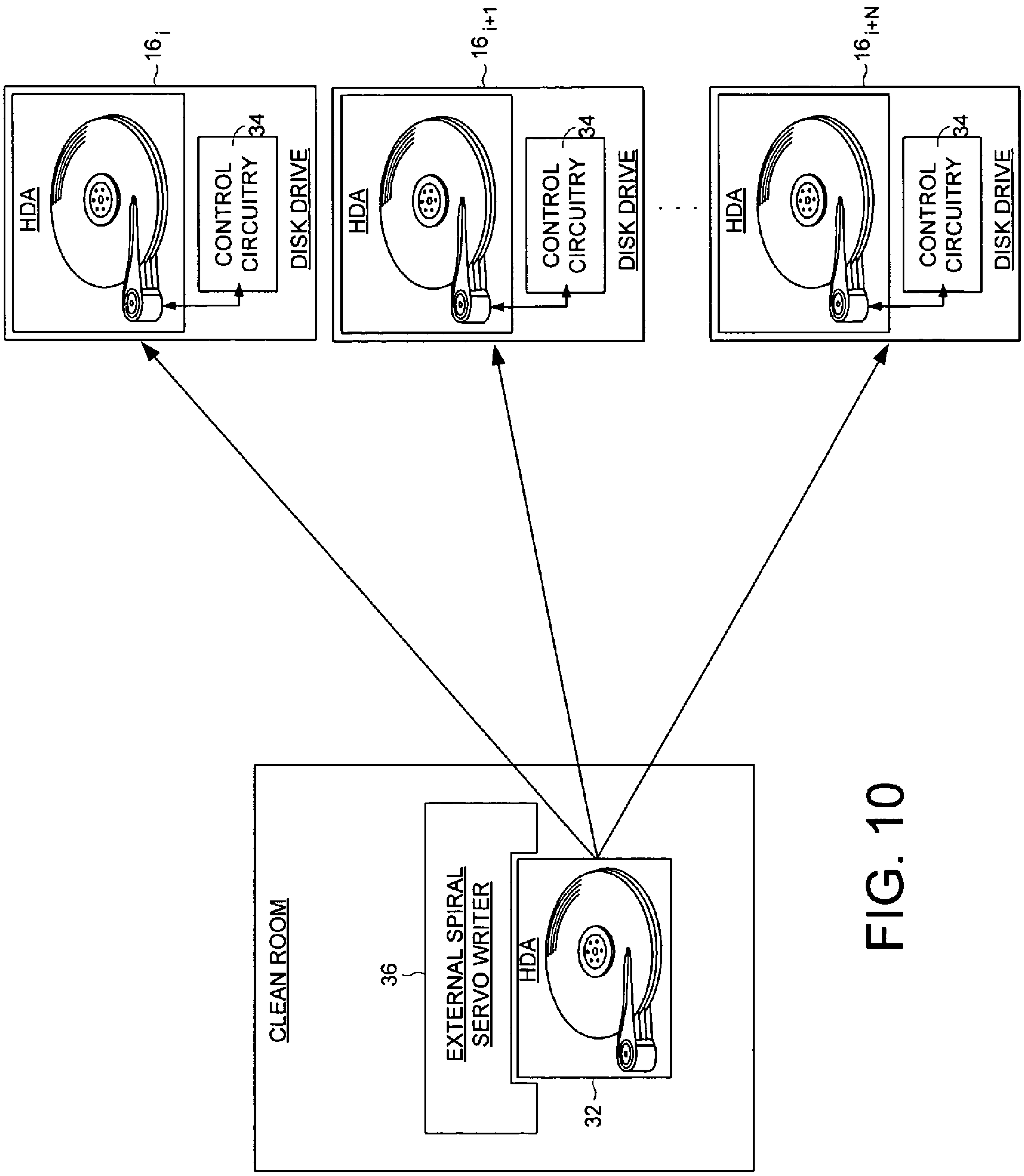

HDA
32
26
28
118
18
30
110
108
PREAMP
120
116
112
READ/WRITE
CHANNEL
106
SERVO
CONTROLLER
114
113
124
CONTROL
CIRCUITRY
122
126
EXTERNAL PRODUCT SERVO WRITER
104

FIG. 8



16_i
16_{i+1}
16_{i+N}
HDA
CONTROL CIRCUITRY
34
DISK DRIVE
EXTERNAL PRODUCT SERVO WRITER
32_i
32_{i+1}
32_{i+N}
104_0
104_1
104_N
CLEAN ROOM
EXTERNAL SPIRAL SERVO WRITER
36
32

FIG. 9



16_i
16_{i+1}
16_{i+N}
HDA
CONTROL CIRCUITRY
34
DISK DRIVE
CLEAN ROOM
36
EXTERNAL SPIRAL SERVO WRITER
HDA
32

FIG. 10

LOCATING AN INITIAL SERVO TRACK IN ORDER TO SERVO WRITE A DISK DRIVE FROM SPIRAL TRACKS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to disk drives for computer systems. More particularly, the present invention relates to locating an initial servo track in order to servo write a disk drive from spiral tracks.

2. Description of the Prior Art

When manufacturing a disk drive, product servo sectors 2_0-2_7 are written to a disk **4** which define a plurality of radially-spaced, concentric data tracks **6** as shown in the prior art disk format of FIG. **1**. Each product servo sector (e.g., servo sector 2_4) comprises a preamble **8** for synchronizing gain control and timing recovery, a sync mark **10** for synchronizing to a data field **12** comprising coarse head positioning information such as a track number, and servo bursts **14** which provide fine head positioning information. During normal operation the servo bursts **14** are processed by the disk drive in order to maintain a head over a centerline of a target track while writing or reading data. In the past, external servo writers have been used to write the product servo sectors 2_0-2_7 to the disk surface during manufacturing. External servo writers employ extremely accurate head positioning mechanics, such as a laser interferometer, to ensure the product servo sectors 2_0-2_7 are written at the proper radial location from the outer diameter of the disk to the inner diameter of the disk. However, external servo writers are expensive and require a clean room environment so that a head positioning pin can be inserted into the head disk assembly (HDA) without contaminating the disk. Thus, external servo writers have become an expensive bottleneck in the disk drive manufacturing process.

The prior art has suggested various "self-servo" writing methods wherein the internal electronics of the disk drive are used to write the product servo sectors independent of an external servo writer. For example, U.S. Pat. No. 5,668,679 teaches a disk drive which performs a self-servo writing operation by writing a plurality of spiral tracks to the disk which are then processed to write the product servo sectors along a circular path. Each spiral track is written to the disk as a high frequency signal (with missing bits), wherein the position error signal (PES) for tracking is generated relative to time shifts in the detected location of the spiral tracks. In addition, the '679 patent generates a servo write clock by synchronizing a phase-locked loop (PLL) to the missing bits in the spiral tracks.

The '679 patent rotates an actuator arm until it contacts an outer diameter (OD) crash stop in order to position the head over an initial servo track at the beginning of the servo writing operation. However, utilizing an OD crash stop to locate the initial servo track may be undesirable for a number of reasons, including the loss of available recording area, or impracticality, such as in disk drives that employ ramp loading/unloading.

SUMMARY OF THE INVENTION

An embodiment of the present invention comprises a method of writing product servo sectors to a disk of a disk drive, the disk drive comprising control circuitry and a head disk assembly (HDA) comprising the disk, an actuator arm, a head connected to a distal end of the actuator arm, and a voice coil motor for rotating the actuator arm about a pivot to position the head radially over the disk. The disk comprises a

plurality of spiral tracks, wherein each spiral track comprises a high frequency signal interrupted at a predetermined interval by a sync mark. The head internal to the disk drive is used to read the spiral tracks to generate a read signal, and the read signal is processed to detect the sync marks in the spiral tracks. An aberration is detected in the detected sync marks in order to locate an initial radial location of the head with respect to the disk. The read signal representing the high frequency signal in the spiral tracks is processed to generate a position error signal (PES) used to maintain the head along a substantially circular target path while using the head internal to the disk drive to write the product servo sectors along the circular target path.

In one embodiment, at least one of the spiral tracks is missing at least one sync mark at the initial radial location, and in one embodiment, every other spiral track is missing at least one sync mark at the initial radial location.

In another embodiment, the sync marks comprise a first pattern at the initial radial location, and the sync marks comprise a second pattern at radial locations different than the initial radial location, wherein the first pattern is different than the second pattern. In one embodiment, detecting the sync marks comprises detecting the first pattern at the initial radial location and detecting the second pattern at radial locations different than the initial radial location.

Another embodiment of the present invention comprises a disk drive comprising a disk including a plurality of spiral tracks, wherein each spiral track comprises a high frequency signal interrupted at a predetermined interval by a sync mark. The disk drive further comprises an actuator arm, a head connected to a distal end of the actuator arm, and a voice coil motor for rotating the actuator arm about a pivot to position the head radially over the disk. Control circuitry within the disk drive writes a plurality of product servo sectors to the disk to define a plurality of radially spaced, concentric data tracks. The head internal to the disk drive is used to read the spiral tracks to generate a read signal which is processed to detect the sync marks in the spiral tracks. An aberration is detected in the detected sync marks in order to locate an initial radial location of the head with respect to the disk. The read signal representing the high frequency signal in the spiral tracks is processed to generate a position error signal (PES) used to maintain the head along a substantially circular target path while using the head internal to the disk drive to write the product servo sectors along the circular target path.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a prior art disk format comprising a plurality of radially spaced, concentric tracks defined by a plurality of product servo sectors.

FIGS. **2**A and **2**B illustrate an embodiment of the present invention wherein an external spiral servo writer is used to write a plurality of spiral tracks to the disk, wherein the sync marks in the spiral tracks are modified at an initial radial location for use in locating an initial servo track.

FIG. **3** illustrates an embodiment of the present invention wherein each spiral track is written over multiple revolutions of the disk.

FIG. **4**A shows an embodiment of the present invention wherein a servo write clock is synchronized by clocking a modulo-N counter relative to when the sync marks in the spiral tracks are detected.

FIG. **4**B shows an eye pattern generated by reading the spiral track, including the sync marks in the spiral track.

FIG. **5** illustrates writing of product servo sectors using a servo write clock generated from reading the spiral tracks, wherein every other spiral track is not written at the initial radial location for locating the initial servo track.

FIG. **6** shows circuitry according to an embodiment of the present invention for generating the servo write clock, and for detecting missing sync marks in the spiral tracks at the initial radial location.

FIG. **7** shows circuitry according to an alternative embodiment of the present invention for generating the servo write clock, and for detecting different sync marks in the spiral tracks at the initial radial location.

FIG. **8** shows an embodiment of the present invention wherein an external product servo writer is used to process the spiral tracks in order to write the product servo sectors to the disk.

FIG. **9** shows an embodiment of the present invention wherein an external spiral servo writer is used to write the spiral tracks, and a plurality of external product servo writers write the product servo sectors for the HDAs output by the external spiral servo writer.

FIG. **10** shows an embodiment of the present invention wherein an external spiral servo writer is used to write the spiral tracks, and the control circuitry within each product disk drive is used to write the product servo sectors.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention comprises a method of writing product servo sectors to a disk of a disk drive. The disk comprises a plurality of spiral tracks, wherein each spiral track comprises a high frequency signal interrupted at a predetermined interval by a sync mark. The head internal to the disk drive is used to read the spiral tracks to generate a read signal, and the read signal is processed to detect the sync marks in the spiral tracks. An aberration is detected in the detected sync marks in order to locate an initial radial location of the head with respect to the disk. The read signal representing the high frequency signal in the spiral tracks is processed to generate a position error signal (PES) used to maintain the head along a substantially circular target path while using the head internal to the disk drive to write the product servo sectors along the circular target path.

The spiral tracks may comprise any suitable pattern and may be written to the disk using any suitable technique, such as using an external writer for writing the spiral tracks to the disk, or stamping the spiral tracks on the disk using magnetic printing techniques. FIGS. **2**A and **2**B show an embodiment wherein a plurality of spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ are written to a disk **18** of a disk drive **16** using an external spiral servo writer **36**. The disk drive **16** comprises control circuitry **34** and a head disk assembly (HDA) **32** comprising the disk **18**, an actuator arm **26**, a head **28** coupled to a distal end of the actuator arm **26**, and a voice coil motor **30** for rotating the actuator arm **26** about a pivot to position the head **28** radially over the disk **18**. A write clock is synchronized to the rotation of the disk **18**, and the plurality of spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ are written on the disk **18** at a predetermined circular location determined from the write clock. Each spiral track $\mathbf{20}_i$ comprises a high frequency signal **22** (FIG. **4**B) interrupted at a predetermined interval by a sync mark **24**.

The external spiral servo writer **36** comprises a head positioner **38** for actuating a head positioning pin **40** using sensitive positioning circuitry, such as a laser interferometer. Pattern circuitry **42** generates the data sequence written to the disk **18** for the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$. The external spiral servo writer **36** inserts a clock head **46** into the HDA **32** for writing a clock track **44** (FIG. **2**B) at an outer diameter of the disk **18**. The clock head **46** then reads the clock track **44** to generate a clock signal **48** processed by timing recovery circuitry **50** to synchronize the write clock **51** for writing the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ to the disk **18**. The timing recovery circuitry **50** enables the pattern circuitry **42** at the appropriate time relative to the write clock **51** so that the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ are written at the appropriate circular location. The timing recovery circuitry **50** also enables the pattern circuitry **42** relative to the write clock **51** to write the sync marks **24** (FIG. **4**B) within the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ at the same circular location from the outer diameter to the inner diameter of the disk **18**. As described below with reference to FIG. **5**, the constant interval between sync marks **24** (independent of the radial location of the head **28**) enables the servo write clock to maintain synchronization while writing the product servo sectors to the disk.

Referring again to FIG. **2**B, while writing the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ at an initial radial location **45** an aberration is written in the sync marks **24** which allows the initial servo track to be located when writing the product servo sectors. Any suitable aberration in the sync marks **24** may be employed in the embodiments of the present invention, such as by disabling the pattern circuitry **42** so that one or more of the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ are not written at the initial radial location, or by writing a different sync mark in one or more of the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ at the initial radial location.

In the embodiment of FIG. **2**B, each spiral track $\mathbf{20}_i$ is written over a partial revolution of the disk **18**. In an alternative embodiment, each spiral track $\mathbf{20}_i$ is written over one or more revolutions of the disk **18**. FIG. **3** shows an embodiment wherein each spiral track $\mathbf{20}_i$ is written over multiple revolutions of the disk **18**. In the embodiment of FIG. **2**A, the entire disk drive **16** is shown as being inserted into the external spiral servo writer **36**. In an alternative embodiment, only the HDA **32** is inserted into the external spiral servo writer **36**. In yet another embodiment, an external media writer is used to write the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ to a number of disks **18**, and one or more of the disks **18** are then inserted into an HDA **32**.

Referring again to the embodiment of FIG. **2**A, after the external spiral servo writer **36** writes the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ to the disk **18**, the head positioning pin **40** and clock head **46** are removed from the HDA **32** and the product servo sectors are written to the disk **18**. In one embodiment, the control circuitry **34** within the disk drive **16** is used to process the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ in order to write the product servo sectors to the disk **18**. In an alternative embodiment described below with reference to FIGS. **8** and **9**, an external product servo writer is used to process the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ in order to write the product servo sectors to the disk **18** during a “fill operation”.

FIG. **4**B illustrates an “eye” pattern in the read signal that is generated when the head **28** crosses over a spiral track **20**. The read signal representing the spiral track comprises high frequency transitions **22** interrupted by sync marks **24**. When the head **28** moves in the radial direction, the eye pattern will shift (left or right) while the sync marks **24** remain fixed. The shift in the eye pattern (detected from the high frequency signal **22**) relative to the sync marks **24** provides the off-track information (position error signal or PES) for servoing the head **28**.

FIG. **4**A shows an embodiment of the present invention wherein a saw-tooth waveform **52** is generated by clocking a modulo-N counter with the servo write clock, wherein the frequency of the servo write clock is adjusted until the sync marks **24** in the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ are detected at a target modulo-N count value. The servo write clock may be generated using any suitable circuitry, such as a phase locked loop

(PLL). As each sync mark **24** in the spiral tracks **20**$_0$-**20**$_N$ is detected, the value of the modulo-N counter represents the phase error for adjusting the PLL. In one embodiment, the PLL is updated when any one of the plurality of sync marks **24** within the eye pattern is detected. In this manner the multiple sync marks **24** in each eye pattern (each spiral track crossing) provides redundancy so that the PLL is still updated if one or more of the sync marks **24** are missed due to noise in the read signal. Once the sync marks **24** are detected at the target modulo-N count values, the servo write clock is coarsely locked to the desired frequency for writing the product servo sectors to the disk **18**.

The sync marks **24** in the spiral tracks **20**$_0$-**20**$_N$ may comprise any suitable pattern, and in one embodiment, a pattern that is substantially shorter than the sync mark **10** in the conventional product servo sectors **2** of FIG. **1**. A shorter sync mark **24** allows the spiral tracks **20**$_0$-**20**$_N$ to be written to the disk **18** using a steeper slope (by moving the head faster from the outer diameter to the inner diameter of the disk **18**) which reduces the time required to write each spiral track **20**$_0$-**20**$_N$.

In one embodiment, the servo write clock is further synchronized by generating a timing recovery measurement from the high frequency signal **22** between the sync marks **24** in the spiral tracks **20**$_0$-**20**$_N$. Synchronizing the servo write clock to the high frequency signal **22** helps maintain proper radial alignment (phase coherency) of the Gray coded track addresses in the product servo sectors. The timing recovery measurement may be generated in any suitable manner. In one embodiment, the servo write clock is used to sample the high frequency signal **22** and the signal sample values are processed to generate the timing recovery measurement. The timing recovery measurement adjusts the phase of the servo write clock (PLL) so that the high frequency signal **22** is sampled synchronously. In this manner, the sync marks **24** provide a coarse timing recovery measurement and the high frequency signal **22** provides a fine timing recovery measurement for maintaining synchronization of the servo write clock.

FIG. **5** illustrates how the product servo sectors **56**$_0$-**56**$_N$ are written to the disk **18** after synchronizing the servo write clock in response to the high frequency signal **22** and the sync marks **24** in the spiral tracks **20**$_0$-**20**$_N$. In the embodiment of FIG. **5**, the dashed lines represent the centerlines of the data tracks. The sync marks in the spiral tracks **20**$_0$-**20**$_N$ are written so that there is a shift of two sync marks **24** in the eye pattern (FIG. **4**B) between data tracks. In an alternative embodiment, the sync marks **24** in the spiral tracks **20**$_0$-**20**$_N$ are written so that there is a shift of N sync marks in the eye pattern between data tracks. In the embodiment of FIG. **5**, each spiral track **20**$_0$-**20**$_N$ is wider than a data track, however, in an alternative embodiment the width of each spiral track **20**$_0$-**20**$_N$ is less than or proximate the width of a data track.

The PES for maintaining the head **28** along a servo track (tracking) may be generated from the spiral tracks **20**$_0$-**20**$_N$ in any suitable manner. In one embodiment, the PES is generated by detecting the eye pattern in FIG. **4**B using an envelope detector and detecting a shift in the envelope relative to the sync marks **24**. In one embodiment, the envelope is detected by integrating the high frequency signal **22** and detecting a shift in the resulting ramp signal. In an alternative embodiment, the high frequency signal **22** between the sync marks **24** in the spiral tracks are demodulated as servo bursts and the PES generated by comparing the servo bursts in a similar manner as the servo bursts **14** in the product servo sectors (FIG. **1**).

FIG. **6** shows details of control circuitry for synchronizing the servo write clock **58** according to an embodiment of the present invention. The read signal **60** emanating from the head **28** is sampled **62**, and the read signal sample values **64** are processed by a sync mark detector **66** for detecting the sync marks **24** in the spiral tracks **20**$_0$-**20**$_N$. The sync mark detector **66** generates a sync mark detect signal **68** applied to a timing recovery circuit **70**. The timing recovery circuit **70** processes the sync mark detect signal **68** to generate a coarse timing recovery measurement, and the read signal sample values **64** representing the high frequency signal **22** in the spiral tracks **20**$_0$-**20**$_N$ to generate a fine timing recovery measurement. The coarse and fine timing recovery measurements are combined to generate a control signal applied to a write oscillator **72** which outputs the servo write clock **58**. The servo write clock **58** clocks operation of write circuitry **74** for writing the product servo sectors **56**$_0$-**56**$_N$ to the disk **18**. The servo write clock **58** is also fed back into the timing recovery circuit **70** and used to generate the coarse timing recovery measurement. The timing recovery circuit **70** generates a sync mark detection window over line **78** for enabling the sync mark detector **66** during a window where a sync mark **24** is expected to occur. The timing recovery circuit **70** also generates a control signal over line **80** to enable the write circuitry **74** to begin writing a product servo sector at the appropriate time.

Referring again to FIG. **5**, when writing the product servo sectors **56**$_0$-**56**$_N$ an initial servo track is located relative to an aberration in the sync marks **24** of the spiral tracks at an initial radial location **45** (FIG. **2**B). In the embodiment of FIG. **5**, every other spiral track is missing (not written) so that the sync marks **24** are missing in every other spiral track. In other embodiments, there may be as few as one missing spiral track and corresponding missing sync mark. Referring again to FIG. **6**, when the timing recovery circuit **70** enables the sync mark detector **66** over line **78** it also enables a missing sync mark detector **82** which detects the missing sync marks when the head is over the initial radial location **45**. For example, the missing sync mark detector **82** may detect no sync mark detect signal **68** over the entire sync mark detection window. Once missing sync marks **24** are detected at every other spiral track, the initial radial location **45** is detected at step **84**, and the write circuitry **74** is enabled over line **86** to begin writing the product servo sectors **56**$_0$-**56**$_N$ along the initial servo track as shown in FIG. **5**.

Any suitable aberration may be detected at the initial radial location **45** for locating the initial servo track. In one embodiment, the sync marks **24** comprise a first pattern at the initial radial location **45**, and the sync marks **24** comprise a second pattern at radial locations different than the initial radial location **45**, wherein the first pattern is different than the second pattern. FIG. **7** shows corresponding control circuitry for synchronizing the servo write clock **58** as well as two sync mark detectors **66**A and **66**B for detecting the initial radial location **45**. The first sync mark detector **66**A generates a sync mark detect signal **68**A when the first pattern is detected at the initial radial location **45**. Once the first sync mark pattern is detected reliably and repeatedly, the initial radial location **45** is detected at step **84** and the write circuitry **74** is enabled over line **86** to begin writing the product servo sectors **56**$_0$-**56**$_N$ along the initial servo track. In one embodiment, only the sync marks **24** comprising the first pattern are written at the initial radial location **45**, and in another embodiment a combination of sync marks **24** comprising the first and second patterns are written at the initial radial location **45** with as few as a single sync mark **24** comprising the first pattern written at the initial radial location **45**. In the embodiment of FIG. **7**, both sync mark detect signals **66**A and **66**B are used by the timing recovery circuitry **70** to synchronize the servo write clock **58**.

FIG. **8** shows an embodiment of the present invention wherein after writing the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ to the disk **18** (FIG. **2**A-**2**B), the HDA **32** is inserted into an external product servo writer **104** comprising suitable circuitry for reading and processing the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ in order to write the product servo sectors $\mathbf{56}_0$-$\mathbf{56}_N$ to the disk **18**. The external product servo writer **104** comprises a read/write channel **106** for interfacing with a preamp **108** in the HDA **32**. The preamp **108** amplifies a read signal emanating from the head **28** over line **110** to generate an amplified read signal applied to the read/write channel **106** over line **112**. The read/write channel **106** comprises circuitry for generating servo burst signals **113** applied to a servo controller **114**. The servo controller **114** processes the servo burst signals **113** to generate the PES. The PES is processed to generate a VCM control signal applied to the VCM **30** over line **116** in order to maintain the head **28** along a circular path while writing the product servo sectors $\mathbf{56}_0$-$\mathbf{56}_N$. The servo controller **114** also generates a spindle motor control signal applied to a spindle motor **118** over line **120** to maintain the disk **18** at a desired angular velocity. Control circuitry **122** processes information received from the read/write channel **106** over line **124** associated with the spiral tracks $\mathbf{20}_0$-$\mathbf{20}_N$ (e.g., timing information) and provides the product servo sector data to the read/write channel **106** at the appropriate time. The product servo sector data is provided to the preamp **108** which modulates a current in the head **28** in order to write the product servo sectors $\mathbf{56}_0$-$\mathbf{56}_N$ to the disk **18**. The control circuitry **122** also transmits control information over line **126** to the servo controller **114** such as the target servo track to be written. After writing the product servo sectors $\mathbf{56}_0$-$\mathbf{56}_N$ to the disk **18**, the HDA **32** is removed from the external product servo writer **104** and a printed circuit board assembly (PCBA) comprising the control circuitry **34** (FIG. **2**A) is mounted to the HDA **32**.

In one embodiment, the external product servo writer **104** of FIG. **8** interfaces with the HDA **32** over the same connections as the control circuitry **34** to minimize the modifications needed to facilitate the external product servo writer **104**. The external product servo writer **104** is less expensive than a conventional servo writer because it does not require a clean room or sophisticated head positioning mechanics. In an embodiment shown in FIG. **9**, a plurality of external product servo writers $\mathbf{104}_0$-$\mathbf{104}_N$ process the HDAs $\mathbf{32}_{i\text{-}i+N}$ output by an external spiral servo writer **36** in order to write the product servo sectors less expensively and more efficiently than a conventional servo writer. In an alternative embodiment shown in FIG. **10**, an external spiral servo writer **36** or an external media writer is used to write the spiral tracks, and the control circuitry **34** within each product disk drive $\mathbf{16}_i$-$\mathbf{16}_{i\text{-}i+N}$ is used to write the product servo sectors.

We claim:

1. A method of writing product servo sectors to a disk of a disk drive, the disk drive comprising control circuitry and a head disk assembly (HDA) comprising the disk, an actuator arm, a head connected to a distal end of the actuator arm, and a voice coil motor for rotating the actuator arm about a pivot to position the head radially over the disk, the disk comprising a plurality of spiral tracks, wherein each spiral track comprises a high frequency signal interrupted at a predetermined interval by a sync mark, the method comprising:

using the head internal to the disk drive to read the spiral tracks to generate a read signal;

processing the read signal to detect the sync marks in the spiral tracks;

detecting an aberration in the detected sync marks in order to locate an initial radial location of the head with respect to the disk;

processing the read signal representing the high frequency signal in the spiral tracks to generate a position error signal (PES) used to maintain the head along a substantially circular target path; and

using the head internal to the disk drive to write the product servo sectors along the circular target path.

2. The method as recited in claim **1**, wherein at least one of the spiral tracks is missing at least one sync mark at the initial radial location.

3. The method as recited in claim **2**, wherein every other spiral track is missing at least one sync mark at the initial radial location.

4. The method as recited in claim **1**, wherein:

the sync marks comprise a first pattern at the initial radial location; and

the sync marks comprise a second pattern at radial locations different than the initial radial location, wherein the first pattern is different than the second pattern.

5. The method as recited in claim **4**, wherein detecting the sync marks comprises detecting the first pattern at the initial radial location and detecting the second pattern at radial locations different than the initial radial location.

6. A disk drive comprising:

(a) a disk comprising a plurality of spiral tracks, wherein each spiral track comprises a high frequency signal interrupted at a predetermined interval by a sync mark;

(b) an actuator arm;

(c) a head connected to a distal end of the actuator arm;

(d) a voice coil motor for rotating the actuator arm about a pivot to position the head radially over the disk; and

(e) control circuitry operable to write a plurality of product servo sectors to the disk to define a plurality of radially spaced, concentric data tracks by:

using the head internal to the disk drive to read the spiral tracks to generate a read signal;

processing the read signal to detect the sync marks in the spiral tracks;

detecting an aberration in the detected sync marks in order to locate an initial radial location of the head with respect to the disk;

processing the read signal representing the high frequency signal in the spiral tracks to generate a position error signal (PES) used to maintain the head along a substantially circular target path; and

using the head internal to the disk drive to write the product servo sectors along the circular target path.

7. The disk drive as recited in claim **6**, wherein at least one of the spiral tracks is missing at least one sync mark at the initial radial location.

8. The disk drive as recited in claim **7**, wherein every other spiral track is missing at least one sync mark at the initial radial location.

9. The disk drive as recited in claim **6**, wherein:

the sync marks comprise a first pattern at the initial radial location; and

the sync marks comprise a second pattern at radial locations different than the initial radial location, wherein the first pattern is different than the second pattern.

10. The disk drive as recited in claim **9**, wherein detecting the sync marks comprises detecting the first pattern at the initial radial location and detecting the second pattern at radial locations different than the initial radial location.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,457,071 B1
APPLICATION NO. : 11/500568
DATED : November 25, 2008
INVENTOR(S) : Edgar D. Sheh and Yilin Cai

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title Page, Item (75) Inventors:
After "Edgar D. Sheh, San Jose, CA (US)", insert -- Yilin Cai, Fremont, CA (US) --.

Signed and Sealed this

Sixteenth Day of March, 2010

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office